

**A Method of Transmitting Synchronous Transport Modules
via a Synchronous Transport Network**

5

This application is based on and claims the benefit of European Patent Application No. 00440160.0 filed Mai 26, 2000, which is incorporated by reference herein.

10

Field of the Invention

00000001, 00000001
The invention relates to a method of transmitting, via a
15 synchronous transport network, a frame-structured
synchronous multiplex signal, being composed of transport
frames having a payload section and an overhead section, in
the payload section of which multiplex units are
multiplexed in accordance with a multiplex hierarchy, and
20 to a multiplexer for a synchronous transport network which
is adapted to transmit a frame-structured, synchronous
multiplex signal of this type.

Background of the Invention

25

A synchronous digital transport network operates for
example in accordance with the recommendations of the ITU-T
(Telecommunication Standardization Sector of International
Telecommunication Union) for SDH (Synchronous Digital
30 Hierarchy) or SONET (Synchronous Optical Network), useful
information being packed in so-called containers. The
containers contain an overhead section known as "path
overhead" together with which they are referred to as
virtual containers VC-N. There are virtual containers of
35 the types VC-11, VC-12, VC-2, VC-3 and VC-4. There are
also contiguously concatenated containers of the types
VC-4-4c and VC-4-16c in the case of SDH, and VC-3-3c,

VC-3-12c and VC-3-48c in the case of SONET. The virtual containers represent multiplex units and are multiplexed in a frame referred to as synchronous transport module STM-N ($N = 1, 4, 16$ or 64), the virtual containers being able to be arbitrarily positioned in the payload section of the transport modules and addressed by a pointer in the overhead section of the transport modules. Smaller virtual containers here are always multiplexed in larger virtual containers. A synchronous transport module in SDH for example always comprises a virtual container VC-4, or in the case of contiguously concatenated containers, a VC-4-nc ($n = 4$ or 16). On the other hand, in the case of SONET each transport module always contains three VC-3s, and in the case of contiguously concatenated containers a VC-3-3c, which corresponds to a VC-4, a VC-3-12c or a VC-3-48c. The described multiplex hierarchy of SDH and SONET is described in detail in ITU-T G.707 (3/96) Chapter 6.

Communications signals transmitted in a synchronous transport network of this kind are thus frame-structured, synchronous multiplex signals being composed of frames each having a payload section and an overhead section. Multiplex units are multiplexed in the payload section of each transport frame in accordance with the multiplex hierarchy specified by the ITU-T. The overhead section contains a pointer to the largest multiplex unit contained in the payload section and one section referred to as RSOH (regenerator section overhead) and one section referred to as MSOH (multiplex section overhead). These contain items of check- and control information which in the case of the RSOH are terminated and regenerated by each regenerator and in the case of the MSOH by each multiplexer. Amongst other things, management functions of the network management system are performed with the aid of these items of check- and control information.

Increasingly, synchronous transport networks are being used not only by public network operators but also as company networks with company network management systems. If a plurality of SDH- or SONET-based sub-networks of a company network are to be connected via the transport network of a public operator, different use of the check- and control information from RSOH and MSOH can lead to conflicts between the network management systems of company transport network and public transport network. Agreements on a uniform use of the check- and control information are necessary and the network management system of the company transport network is restricted with regard to the management of its company network. Thus for example the multiplex structure cannot be changed from 16 x VC-4 to 1 x VC-4-16c in a STM-16 without the agreement of the public network operator.

Optical networks via which so-called optical channels (OCh) are to be transmitted are also currently in development. These networks are to be capable of transparently transmitting signals with any bit rate and therefore these future optical networks will also be capable of transparently transporting frame-structured communications signals from a company network. However as yet no binding standard exists for this purpose and moreover the construction of such an optical network would require the replacement of all the network elements.

Summary of the Invention

An object of the invention is to provide a method with which it is possible to use the current SDH- or SONET-based transport networks to connect synchronous digital sub-networks of private operators without the need for agreements between the network management systems and without restrictions upon the private operator. Another objective of the invention is to provide a multiplexer for

The object is achieved by mapping the frames to be
10 transmitted, including their unchanged overhead sections,
as payload in a concatenation of newly formed multiplex
units.

An advantage of the invention is that it facilitates the construction of SDH- or SONET- based virtual private
35 networks (VPN). Other advantages are that it is also possible to transmit frame-structured synchronous communications signals in the case of which overhead bytes

10

15

20

25

30

35

Figure 3 illustrates the multiplex structure for the process according to the invention for a SONET-based transport network,

5 Figure 4a, b
illustrate a first example for the mapping of frames of the type STM-4 in a SDH-based transport network,

10 Figure 5a, b
illustrate a second example for the mapping of frames of the type STM-16,

Figure 6 illustrates the construction of a virtual private
15 network with the arrangement according to Figure 1,

Figure 7 illustrates the logical construction of the
virtual private network according to Figure 6 and
20

Figure 8 is a block diagram of a multiplexer according to the invention.

Detailed Description of the Invention

25 Figure 1 shows an application of the invention as first exemplary embodiment. Two sub-networks SN1 and SN2 and one individual network element R6 of a private operator are connected to one another via a public transport network
30 WAN. The first sub-network SN1 contains three network elements R1, R2 and R3 which are connected to form a ring network. The second sub-network SN2 contains two network elements R4 and R5 which are connected to one another via two redundant lines. The network elements are
35 interconnected within the sub-networks SN1, SN2 via SDH interfaces via which the frame-structured synchronous

multiplex signals are transmitted. The multiplex signals consist of synchronous transport modules of the type STM-4.

Each of the network elements R1-R6 is an IP router in each case of a data network via which a plurality of IP-capable terminals of the operator are interlinked. The SDH-connections within the sub-networks represent the operator's backbone network via which the IP-traffic between the data networks is handled for example by means of the method for "IP via SDH" known from IETF RFC 1619 and 1661.

The sub-networks SN1, SN2 and the individual router R6 are now likewise to be capable of exchanging transport modules of the type STM-4 via the transport network WAN in order that the sub-networks are connected to one another. For this purpose it is necessary for the transport modules to be transmitted unchanged between the sub-networks, i.e. without terminating the overhead of the transport modules in the transport network WAN, so that the operator's backbone network is not subject to any restrictions regarding the use of the overhead bytes.

A basic principle of the invention is now to transmit the synchronous transport modules in transparent fashion as payload in a concatenation of virtual containers. For this purpose new multiplex units of the type VC-4 are formed in the transport network and concatenated with one another to form a virtual concatenation VC-4-nv. The transport frames to be transmitted between the sub-networks are packed as payload into the payload sections of the multiplex units of this virtual concatenation. The newly formed multiplex units are then embedded in the payload section of newly formed transport modules and transmitted via the transport network WAN.

The mapping illustrated in Figure 2 is used for this purpose. Figure 2 shows a container C-4 which, by the addition of an overhead section known as POH (path overhead), is extended to form a virtual container VC-4.

- 5 The container C-4 contains data of a payload signal which are to be transmitted. The virtual container VC-4 represents the multiplex unit. By the addition of a pointer indicating the phase position of the virtual container VC-4 in a superordinate transport frame, the VC-4
10 becomes a so-called AUG (administrative unit group).

- Alternatively, as shown in the second from bottom line of the Figure, an AUG can also contain a container of a contiguous concatenation C-4-nc. Such contiguous
15 concatenations are used when, in a transport module STM-N ($N = 4, 16$ or 64) which is greater than a STM-1, the payload sections of the containers C-4 contained therein are to be jointly used for one single transmission channel.

- At this point it should also be noted that the
20 nomenclature of the draft version of ITU-T G.707 (Temporary Document 48R1 (PLEN), 4/00), currently discussed in ITU-T SG15, differentiates the AUG into AUGN ($N = 1, 4, 16$) corresponding to the size of the transport module in which the AUG is transported. Accordingly a STM-16 always
25 contains an AUG16. This AUG16 can contain either a contiguous concatenation of 16 VC-4s (VC-4-16c) or however four byte-wise interleaved AUG4s. The AUG4s can in turn contain either a contiguous concatenation VC-4-4c or four type-wise interleaved AUG1s.

30

- In a next step a transport frame STM-N is formed, where N can be 1, 4, 16 or 64. For $N = 1$, as already mentioned, the transport frame contains an overhead section comprising MSOH, RSOH and pointer, and a payload section. The payload
35 section comprises exactly one AUG1 and the pointer addresses the start of the VC-4 in the payload section. Higher transport frames ($N = 4, 16, 64$) are formed by byte-

09063321.052401

wise interleaving of N AUGIs to form AUGN. A STM-N thus contains exactly one AUGN which in turn contains exactly N AUGIs in accordance with the described multiplex rule. The manner in which the AUGs are interleaved in the STM-N is 5 described in detail in the draft version of ITU-T G.707 (Temporary Document 48R1 (PLEN), 4/00 Chpt. 7.1.

The thus formed transport frame STM-N is now periodically repeated with a frame clock, where each new frame naturally 10 contains new data bits of the payload signal to be transmitted. The synchronous data stream formed from the periodically repeated transport frames is transmitted in the sub-networks of the private operator and transports all the payload data, i.e. in the exemplary embodiment the IP 15 packets, which are transmitted between the individual routers in the operator's backbone network. This data stream is now also to be transmitted as a whole via the public transport network WAN in order to connect the sub-networks SN1, SN2 and the individual router R6 to form a 20 whole network.

For this purpose, at the interface between public transport network and private company network new multiplex units VC-4 are generated by the multiplexer and concatenated to 25 form a virtual concatenation VC-4v. Such a virtual concatenation of virtual containers VC-4 is known *per se* and described in ITU-T G.707 Chpt. 8.1.7. The number of multiplex units in the concatenation is dependent upon the size of the transport module to be transmitted. If, as in 30 the exemplary embodiment, a STM-4 is to be transmitted, the public network operator requires five multiplex units of the type VC-4. Two VC-4s would be required for STM-1, seventeen VC-4s for STM-16 and sixty eight VC-4s for STM-64. In the mapping shown in Figure 2 this is schematically 35 indicated by parallel paths in the flow diagram.

The virtual containers VC-4 of the concatenation are now combined to form a new AUG in accordance with the above described multiplex rule. As is known, a STM-N can accommodate exactly N VC-4s. As the number of concatenated
5 containers (2, 5, 17 or 68) does not correspond to the permissible values for N (1, 4, 16, 64), the next larger transport frame must be used. The remaining capacity of the transport frame can be filled with further multiplex units VC-4. This is illustrated in Figure 2 by a further
10 tributary for the upper AUG.

As this is a virtual concatenation, alternatively to a next larger transport frame it is also possible to use several smaller transport frames. The individual multiplex units
15 of the virtual concatenation thus need not necessarily be transmitted via the same interface but can also take different paths through the transmission network, transit time differences being compensated by intermediate storage in the receiving network element. However it is
20 advantageous to transmit the virtual concatenation in one single transport module as this minimizes the transit time differences.

Now a new transport frame STM-N is formed and the AUG is
25 embedded in the payload section of this new transport frame. The periodic repetition of this transport frame always with a new payload gives rise to a new synchronous data stream which is transmitted via the transport network WAN of the public operator. In the transmission the
30 overhead of the newly formed transport frames is exclusively available for control and management functions of the public transport network. In accordance with the ITU-T recommendations the public operator can access the overhead bytes with no further restrictions without
35 conflicting with the network management system of the private operator, as the transport frames formed by its

00663321.052401

network elements, together with overhead, are transported as payload through the public transport network.

Figure 3 illustrates the corresponding mapping for a SONET-based transport network. Instead of a VC-4, in SONET one always uses three VC-3s which are combined to form an AUG.

In SONET the transport modules are known not as STM-N but as OC-N (optical) or STS-N (electrical) where $N = 3, 12, 48$ or 192 . Similarly to a STM-N, they also contain a RSOH and a MSOH in the overhead section. However they include not only one pointer, but, in accordance with the number of multiplex units of the highest hierarchy stage (VC-3), three pointers to the three VC-3s of the AUG. The number of virtual containers VC-3-Xv for the transport modules OC-3, OC-12 and OC-48 which are to be virtually concatenated for the transport is shown in the Figure.

In addition to the mappings illustrated in Figures 2 and 3, mixed forms are also possible, in the case of which for example the private operator runs a SONET-based network and connects its sub-networks via a SDH-based transport network of the public operator.

Figures 4a and 4b schematically illustrate how in the first exemplary embodiment the transport frames from the private network which are to be transported are embedded in the public operator's concatenated multiplex units which are to be newly formed. Figure 4a firstly shows the construction of the STM-4 of the private operator. The construction corresponds to the specifications of ITU-T G.707. The STM-4 has one single overhead section with a length of $N \times 9$ columns and one single payload section containing an AUG4 formed by byte-wise interleaving of four AUG1s. However for greater clarity a different designation has been selected in Figure 4a. It should be noted that here merely a different designation has been selected while the actual

As illustrated in Figure 4a, the STM-4 consists of four byte-wise interleaved frames of the type STM-1**. The designation STM-1** was selected to indicate that these are not STM-1 frames, although the STM-1** frames formally correspond to a STM-1 frame in construction and appearance.

Each of the four STM-1**s consists of an AUG1 and a part of the overhead section of the STM-4. As already stated, the STM-4 contains only one single overhead section consisting of 4*9 columns. However in Figure 4a this overhead section has been shown split into four equal parts, one quarter of the overhead section in each case being assigned to one STM-1** as overhead of this fictive frame. As the four STM-1**s are interleaved byte-wise, the four parts exactly form the actual overhead section of the STM-4.

The overhead section consists of RS-OH, MS-OH and AU-pointer AU-PTR. The designations for each of the overhead sections of the four STM-1**s have also been chosen accordingly in Figure 4a. The overhead section is adjoined by the payload section which, in accordance with the fictive division into four STM-1**s, has likewise been shown divided into four parts, one part of the payload section in each case being assigned to one STM-1**. Each of the parts of the payload section contains a virtual container VC-4 consisting of a container C4 and a container overhead POH. However, for clarity, and without limiting the generality, in the Figure the containers contained in the payload section have been shown directly adjoining the overhead section of the transport frame, i.e. in the exemplary embodiment the AU-pointers would all be zero. In actuality the VC-4 can be arbitrarily positioned in the

payload section of a STM-1** and extend into the payload section of the following frame. This is a basic characteristic of synchronous transport networks (SDH, SONET): Clock differences between individual network elements of the transport network are compensated by AU pointer justification and corresponding displacement of the virtual container.

A STM-1** has 9 rows and 270 columns. The columns 1-9 are occupied by the quarter of the overhead section assigned to the STM-1** while the other columns 10-270 represent the part of the payload section assigned to the STM-1**.

Figure 4b illustrates the five virtual containers VC-4v of the virtual concatenation VC-4-5v. The upper part of the Figure provides a detailed view of the first virtual container VC-4v#1, while the other four virtual containers have been illustrated in reduced form. In reality however all five virtual containers are of the same length.

Each of the virtual containers is assigned an AU-pointer AU-PTR-v1, ..., AU-PTR-v5 indicating its phase position in the superordinate transport module. VC-4 and AU-pointer represent an AUG1. Since this is a virtual concatenation, all five AU-pointers are determined independently of one another as the five VC-4s can be transmitted in any phase position relative to one another. The column numbers of 1 to 261 are indicated at the upper edge of the VC-4 and the row numbers of 1 to 9 of the AUG are indicated at the right-hand edge.

The first VC-4 commences in column 1 with the POH (path overhead). This is followed by the payload section of the VC-4 in which the overhead sections of the STM-4 to be transported are packed. Columns 2 to 10 contain the overhead section of the first STM-1** from the STM-4, columns 11 to 19 contain the overhead section of the second

0063321.052401
104250.12229960

STM-1**, columns 20 to 28 contain the overhead section of the third STM-1**, and columns 29 to 37 the overhead section of the fourth STM-1**. These are adjoined in columns 38 to 41 by the container overheads POH of the four multiplex units contained in the four STM-1**s. The other columns 42 to 261 are reserved for proprietary or future use by the network management systems of public and private network operator and if they are not used are filled with hexFF. By way of example it has been shown that columns 42 to 50 are reserved for the public operator and columns 51 to 269 for the private operator.

The second VC-4 of the concatenation likewise contains a container head POH#v2. Adjoining the container overhead the first container C4 from the STM-4 frame to be transmitted is attached as payload. Correspondingly, the third VC-4 of the concatenation contains the second container C4 from the STM-4 frame, the fourth VC-4 contains the third container C4 and finally the fifth VC-4 contains the fourth container C4. In this way the entire payload content of the STM-4 frame to be transmitted is distributed between the virtual containers two to five of the concatenation, while all the items of control information from the overhead sections are embedded in the first VC-4.

The corresponding mapping for a transport frame of the type STM-16 to be transmitted from the private network is shown in Figures 5a and 5b. The STM-16 to be transmitted consists of 16 byte-wise interleaved STM-1**s which each contain a part of the frame overhead comprising RS-OH, MS-OH and AU pointer. These in turn are in each case adjoined by a virtual container of the type VC-4 consisting of a container overhead POH and a payload section C4. Only the first two STM-1** frames and the last, i.e. sixteenth, STM-1** frame have been shown by way of example in Figure 5a.

Figure 5b illustrates how this STM-16 frame is packed into a virtual concatenation of seventeen VC-4s. By way of example Figure 5b shows only the first three VC-4s and the last, i.e. the seventeenth, VC-4 of the concatenation. As in the previous example the first VC-4 contains the frame overheads of the sixteen STM-1** frames of the STM-16 to be transmitted and the container overheads POH of the VC-4s from the STM-16. As in the previous example, the column numbers of the AUG are indicated at the upper edge and the row numbers at the right-hand edge. The AU-pointer consists of nine bytes. In the first column of the AUG the VC-4 commences with its POH. Columns 2 to 10 contain the overhead section of the first STM-1** from the STM-16 to be transmitted, columns 11 to 19 contain the overhead section of the second STM-1** etc. Finally columns 137 to 145 (137 = 2 + 15*9) contain the overhead section of the sixteenth STM-1** frame to be transmitted. This is adjoined in columns 146 to 161 by the container overheads POH of the STM-1** to be transmitted. Rows 162 to 261 are reserved for proprietary or future use by the network management systems of public and private network operator and if they are not used are filled with hexFF. By way of example it has been shown that columns 162 to 170 are reserved for the public operator and columns 171 to 261 are reserved for the private operator.

Figure 6 schematically illustrates how the transmission of the transport frames between the sub-networks of the private operator takes place via the public transport network. This is based on the same arrangement as in Figure 1 but the public transport network WAN has been shown in detail. It consists of two ring networks connected to one another at two locations. The ring networks consist of network elements ADM, DXC which are bidirectionally connected to one another. Such network elements are add/drop multiplexers ADM or digital cross-connects DXC. Each of the network elements R2, R4 and R6

multiplexers, the transport frames to be transmitted between the sub-networks SN1, SN2 and R6 are packed into a concatenation of virtual containers in accordance with the process already explained in detail, and are transmitted in newly formed transport frames. Between the network elements R2, R4 and R6 this gives rise to a virtual ring network VR via which the multiplex signals structured into STM-4 transport frames are transmitted.

Figure 8 illustrates a multiplexer ADM with which the transmission process according to the invention can be executed. This is an add/drop multiplexer as used for example in the public transport network WAN in Figure 6. The multiplexer in each case comprises an east- and a west- input IN EAST, IN WEST and an east- and a west-output

A data stream structured to form STM-4 frames is received at the tributary input 81. In the input 81, in accordance with the mapping described with reference to Figure 4a and 4b, five virtual containers VC-4 are formed for each received STM-4 frame and virtually concatenated to one another. A STM-4 frame is in each case packed into these five VC-4s. The concatenated, five VC-4-5vs are then fed to the VC-4 matrix and fed from the matrix to a

corresponding output, e.g. the west-output OUT_WEST where they are interleaved with other VC-4s in the STM-16 frames.

The opposite direction is illustrated by way of example at 5 the tributary output 82. The VC-4 matrix switches to the output 82 a concatenation VC-4-5v of five VC-4s which for example are contained in the STM-16 frame received at the west-input IN_WEST. At the output 82 the useful information of the five VC-4s is read out from the payload 10 sections thereof, intermediately stored in a buffer memory, and assembled in the original phase position to form a STM-4 frame which is then transmitted at the output 82. To assemble the STM-4 frame, the frame overheads packed in accordance with the mapping illustrated in Figure 4b are 15 read out from the first VC-4 and used as frame overheads for STM-1 frames to be newly formed. Then the container heads POH are read out and attached to the containers C4 contained in the payload section of the following four VC-4s. Then the thus newly formed VC-4s are inserted into the 20 STM-1 frames in accordance with the value of the AU-pointer present in the frame overhead and the STM-1 frames are interleaved byte-wise to form a STM-4 frame. The multiplexer ADM thus operates simultaneously as multiplexer and demultiplexer.

25

The virtual concatenation of VC-4s for the transportation of STM-N frames has been used throughout in the exemplary embodiments. The virtual concatenation provides advantages in the transmission as in interposed network elements no 30 attention need be paid to the phase position of the individual concatenated VC-4s and thus no measures need be taken to suppress differential phase fluctuations between the VC-4s. However it is also possible to use a contiguous concatenation of VC-4s for the transmission according to 35 the invention of STM-N frames. In SONET-based transport networks a concatenation of VC-3s is used instead of the

concatenation of VC-4s since, as already mentioned [...]
the VC-4 [...].

The invention can also be used advantageously internally in network elements in order to switch entire transport frames using a switching matrix designed only for virtual containers. In this case a received transport frame is embedded in a concatenation of virtual containers at the input end whereupon the virtual containers of the concatenation are switched by the switching matrix to an output where they are removed again and the original transport frame is re-assembled. This facilitates the switching of whole transport frames by a matrix which in itself can only switch virtual containers. As a result the frame overhead of the transport frames need not be terminated at the input end and re-generated at the output end.

At least in theory, the process according to the invention
20 can be iteratively interleaved as often as desired, i.e. a
first frame-structured synchronous multiplex signal can be
transmitted as payload of a first virtual concatenation in
a second frame-structured synchronous multiplex signal
which in turn is transported as payload of a second virtual
25 concatenation in a third frame-structured synchronous
multiplex signal etc.